Nutrición Hospitalaria

El papel del puntaje simple de síndrome metabólico pediátrico y los puntajes Z de gravedad del síndrome metabólico en la identificación del síndrome metabólico entre adolescentes obesos

The role of pediatric simple metabolic syndrome score and metabolic syndrome severity z-scores in identifying metabolic syndrome among obese adolescents

10.20960/nh.05676

06/06/2025

OR 5676

The role of pediatric simple metabolic syndrome score and metabolic syndrome severity z-scores in identifying metabolic syndrome among obese adolescents

El papel del puntaje simple de síndrome metabólico pediátrico y los puntajes Z de gravedad del síndrome metabólico en la identificación del síndrome metabólico entre adolescentes obesos

Muammer Büyükinan[1], Sadiye Sert[2], Ahmet Fatih Yilmaz[1]

[1]Department of Pediatric Endocrinology. Selcuk University Medical School; and [2]Department of Pediatrics. Konya Beyhekim Training and Research Hospital. Konya, Turkey

Received: 17/12/2024
Accepted: 09/04/2025
Correspondence: Sadiye Sert. Department of Pediatrics. Konya Beyhekim Training and Research Hospital. Beyhekim, Devlethane Sokak No: 2/C. 42060 Selçuklu/Konya, Turkey
e-mail: sadiyesert@yahoo.com.tr

Authors´ contribution: concept: S.S., M.B. and A.F.Y.; design: S.S., M.B. and A.F.Y.; supervision: S.S., and M.B..; materials: S.S., M.B. and A.F.Y.; data collection and/or processing: S.S., M.B. and A.F.Y.; analysis and/or interpretation: S.S., M.B.; literature review: S.S., and M.B.; writing: S.S., and M.B.; critical review: S.S., and M.B. M.B. and S.S. contributed equally to the article.

Ethics Committee Approval: Selçuk University Ethics Committee approval was received for this study (date: 29.02.2024/No: 81).

Conflicts of interest: the authors declare no conflicts of interest.

Artificial intelligence: the authors declare not to have used artificial intelligence (AI) or any AI-assisted technologies in the elaboration of the article.

ABSTRACT

Background: the aim of our study was to evaluate the effectiveness of the pediatric simple metabolic syndrome score (PsiMS) and the metabolic syndrome severity (MetSS) z-score in determining the risk of metabolic syndrome (MetS) in obese adolescents, as well as to assess their correlation with metabolic variables and establish diagnostic cut-offs for MetS.

Materials and methods: this prospective cross-sectional study was conducted at two medical centers from March 202*4* to June 2024, including a total of 24*6* obese adolescents.

Results: obese adolescents diagnosed with MetS exhibited notably elevated PsiMS and MetSS z-score values. Significant positive correlations were identified between the PsiMS and BMI z-score, total cholesterol, gamma-glutamyl transferase, uric acid, insulin levels, and the Homeostasis Model Assessment of Insulin Resistance (HOMA-IR). Positive relationships were also observed between the MetSS z-score and hip circumference, alanine aminotransferase, gamma-glutamyl transferase, uric acid, insulin, HOMA-IR, and the PsiMS. The PsiMS demonstrated an area under the curve (AUC) of 0.75*3* with a threshold of 4.5242, resulting in sensitivity and specificity values of 68.*2* % and 68.*4* %, respectively. The MetSS z-score exhibited an AUC of 0.88*5* with a threshold of 1.1145, yielding sensitivity and specificity values of 80.*7* % and 80.*4* %, respectively. The comparison of AUC values between the PsiMS and MetSS z-scores was statistically significant.

Conclusion: our findings indicate that the rates of MetS diagnosis using the PsiMS and MetSS z-scores—both continuous metrics for assessing MetS—were significantly higher in adolescents compared to those identified through traditional dichotomous diagnostic methods.

Keywords: Adolescent. Cardiometabolic risk factors. Insulin resistance. Metabolic syndrome. Pediatric obesity.

RESUMEN

Antecedentes: el objetivo de nuestro estudio fue evaluar la efectividad del puntaje de síndrome metabólico simple pediátrico (PsiMS) y el puntaje z de severidad del síndrome metabólico (MetSS) para determinar el riesgo de síndrome metabólico (MetS) en adolescentes obesos, así como evaluar su correlación con variables metabólicas y establecer puntos de corte diagnósticos para el MetS.

Materiales y métodos: este estudio transversal prospectivo se llevó a cabo en dos centros médicos desde marzo de 202*4* hasta junio de 2024, incluyendo un total de 24*6* adolescentes obesos.

Resultados: los adolescentes obesos diagnosticados con MetS mostraron valores notablemente elevados de PsiMS y puntajes z de MetSS. Se identificaron correlaciones positivas significativas entre el PsiMS y el puntaje z de IMC, colesterol total, gamma-glutamiltransferasa, ácido úrico, niveles de insulina y el Modelo de Evaluación de Homeostasis de Resistencia a la Insulina (HOMA-IR). También se observaron relaciones positivas entre el puntaje z de MetSS y la circunferencia de cadera, la alanina-aminotransferasa, la gamma-glutamiltransferasa, el ácido úrico, la insulina, el HOMA-IR y el PsiMS. El PsiMS mostró un área bajo la curva (AUC) de 0,75*3* con un umbral de 4,5242, resultando en valores de sensibilidad y especificidad del 68,*2* % y 68,*4* %, respectivamente. El puntaje z de MetSS presentó un AUC de 0,88*5* con un umbral de 1,1145, arrojando valores de sensibilidad y especificidad del 80,*7* % y 80,*4* %,

respectivamente. La comparación de los valores de AUC entre el PsiMS y los puntajes z de MetSS fue estadísticamente significativa.
Conclusión: nuestros hallazgos indican que las tasas de diagnóstico de MetS utilizando los puntajes de PsiMS y MetSS, ambas métricas continuas para evaluar el MetS, fueron significativamente más altas en adolescentes en comparación con aquellos identificados a través de métodos diagnósticos dicotómicos tradicionales.

Palabras clave: Adolescente. Factores de riesgo cardiometabólico. Resistencia a la insulina. Síndrome metabólico. Obesidad pediátrica.

INTRODUCTION

The rising prevalence of childhood obesity has raised significant concerns about associated conditions, such as metabolic syndrome (MetS). In recent years, the global surge in adolescent obesity has led to a substantial increase in MetS rates among this age group (1,2). MetS, a well-established multifactorial condition, is closely linked to an elevated risk of cardiovascular disease (CVD) and type *2* diabetes. Studies suggest that the metabolic profile of MetS in childhood persists into adulthood, posing a long-term health risk (3-5). However, defining MetS in adolescents remains challenging due to the lack of universally accepted reference values for each component in this age group (6,7).

While the binary definition of MetS is effective for diagnosing adults, its applicability to adolescents is uncertain, given the lower prevalence of MetS and the limited number of large-scale studies. The American Diabetes Association and the European Association for the Study of Diabetes recommend using a continuous scoring system rather than a binary approach for diagnosing MetS in adolescents (8,9). Various methodologies, including z-scores, factorial analysis, and principal components analysis, have been employed in studies to

develop continuous MetS scores tailored to different populations (10,11). The utilization of continuous MetS risk scores has been proposed to enhance understanding of the relationships between risk factors and outcomes in researches (5,9). Efforts have been made to introduce simplified MetS scoring systems, such as the simple metabolic syndrome (siMS) score (12), including a pediatric version (13,14), to provide practical and universal tools for MetS assessment in diverse settings. Despite variations in the variables included in calculations across studies, attempts have been made to establish these simplified scoring systems. To date, there has been no research evaluating the effectiveness of the pediatric simple metabolic syndrome score (PsiMS) and the metabolic syndrome severity (MetSS) z-score, both of which are continuous MetS risk scores in determining the risk of MetS among obese adolescents. The aim of our study was to evaluate the effectiveness of the PsiMS and the MetSS z-score in determining the risk of MetS in obese adolescents, as well as to assess their correlation with metabolic variables and establish diagnostic cut-offs for MetS.

MATERIALS AND METHODS

Participants

This study was performed in accordance with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Selçuk University (Date: 29.02.2024/No: 81), and informed consent was obtained from the parents of participating adolescents. A cross-sectional study was conducted at the pediatric outpatient clinic of Konya Beyhekim Training and Research Hospital and the Pediatric Endocrinology Clinic of Selçuk University Hospital from March 202*4* to June 2024. The sample size was determined based on a study by Vukovic et al. (13) on the PsiMS score, using the G*Power 3.1.9.*7* software. With a *5* % alpha error, a 1*0* % effect size, and 8*0* % power, a minimum sample size of 24*4* adolescents was required, and this target was achieved.

A total of 24*6* obese adolescents were randomly assigned to MetS and non-MetS groups according to the International Diabetes Federation (IDF) consensus criteria for pediatric MetS. The diagnosis of pediatric MetS, as per IDF guidelines, required abdominal obesity (waist circumference [WC] ≥ 90th percentile or adult cut-off if lower) and a combination of at least two of the following clinical indicators: low HDL-C levels, elevated triglycerides, increased fasting plasma glucose (FPG) levels, and elevated blood pressure (BP) (15). Exclusion criteria included individuals with systemic illnesses, those on specific medications, or conditions affecting insulin function.

Anthropometric measurements

Anthropometric measurements were conducted for all subjects, involving height and weight assessments using a Harpenden stadiometer and an electronic scale. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Adolescents with BMIs at or above the 95th percentile based on reference curves for this age group were classified as obese. Standard deviation scores for BMI (BMI-SDS) were obtained from national growth charts (16,17). Waist circumference and hip circumference measurements were taken to calculate the waist-to-height ratio (WHtR) and waist-to-hip ratio (WHR) (18). Pubertal development stages were assessed using Tanner criteria, with patients exhibiting sexual maturation between Tanner stages *2* and 5. Blood pressure measurements were obtained following a standardized resting period of at least *5* minutes, using a sphygmomanometer with an appropriately sized pediatric cuff.

Laboratory assessment

Laboratory assessments involved the collection of morning venipuncture blood samples from participants after an overnight fast. These samples were analyzed for serum glucose, insulin levels, and other relevant parameters. Serum lipids were measured using

standard enzymatic techniques on an Abbott Diagnostics c16000 chemistry analyzer, while serum insulin concentrations were determined using the IMMULITE immunoassay system from Siemens Healthcare Diagnostics.

Insulin sensitivity measurement

Insulin sensitivity was evaluated using the homeostasis model assessment of insulin resistance (HOMA-IR), with values above 3.16 indicating insulin resistance (19,20).

Calculation of PsiMS score and MetSS z-score

The calculations of the PsiMS score and the MetSS z-score were based on specific formulas that incorporated various parameters related to MetS components. The PsiMS score formula included WC, FPG, triglycerides, systolic BP, and HDL-C levels (13). On the other hand, the MetSS z-score was calculated using height, weight, WC, systolic BP, HDL-C and triglyceride, and FPG (21).

Statistical analysis

We employed the Shapiro-Wilk test to examine the distribution of parameters. Normally distributed variables were presented as mean ± standard deviation, while non-normally distributed variables were described as median with interquartile range (IQR). Categorical variables were summarized using frequency and percentage values. Various statistical tests, such as the Mann-Whitney U-test, independent t-test, and chi-square test, were used for comparative analyses. Bivariate associations among continuous variables were explored using Spearman's rank correlation test, and analyses of variance were conducted to compare all groups. Multiple logistic regression analyses were performed to identify potential risk factors associated with continuous MetS (cMetS) scores. The predictive performance of the PsiMS score and MetSS z-score in detecting MetS in obese adolescents was evaluated through receiver operating

characteristic (ROC) curve analysis. Optimal cut-off values were determined, and the area under the ROC curve was calculated to assess sensitivity and specificity. The Youden index was calculated using the formula: "Youden Index = Sensitivity + Specificity – 1." The interpretation of the area under the curve (AUC) was based on specific criteria: an AUC of 0.*5* indicates a non-informative or chance-level test, while values between 0.*5* and 0.*7* suggest lower accuracy, 0.*7* to 0.*9* indicate moderate accuracy, 0.*9* to 1.*0* signify high accuracy, and an AUC of 1.*0* represents a perfectly discriminatory test. To assess and compare the performance of various methods for calculating cMetS scores, the AUC values were compared using the Hanley and McNeil method. The statistical analyses were conducted using SPSS software for Windows, version 21.0, and figures were generated using GraphPad Prism 9.0.

RESULTS

Demographic and laboratory characteristics of participants

In this investigation, we scrutinized the demographic and laboratory profiles of 24*6* obese adolescents, including 12*8* females and 11*8* males. The cohort exhibited a median age of 13.*7* years (interquartile range [IQR]: 3.6) and a median BMI of 3*0* kg/m² (IQR: 5.6). Among the obese adolescents, 8*8* individuals (35.*7* %) were diagnosed with MetS. No significant disparities were noted in sex and age between those with and without MetS. Adolescents with MetS exhibited distinct metabolic and anthropometric characteristics, including higher values for BMI, WC, WHR, blood pressures (systolic, diastolic, and mean), serum triglycerides, FPG, insulin levels, and HOMA-IR. They also had lower levels of HDL-C compared to those without MetS. Additionally, obese individuals with MetS displayed significantly higher PsiMS and MetSS z-score values (Table I, Fig. 1). Significant differences in these scores were observed with an increase in the number of MetS components (Table II).

Positive associations were observed between the PsiMS score and BMI z-score, total cholesterol, GGT, uric acid, insulin levels, and HOMA-IR (Table III). Similar correlations were noted in both the non-MetS and MetS groups regarding total cholesterol in relation to the PsiMS score. Positive correlations were also found between the MetSS z-score and HC, ALT, GGT, uric acid, insulin, HOMA-IR, ferritin, and the PsiMS score (Table IV).

Subsequent multiple regression analyses in the entire study group highlighted triglyceride (β = 0.873, $p < 0.0001$) and HDL-C levels (β = -0.201, $p < 0.0001$) as independent variables significantly impacting the PsiMS score. In the MetS cohort, triglyceride (β = 0.906, $p < 0.001$) and HDL-C levels (β = -0.089, p: 0.007) emerged as exclusive independent contributors to the PsiMS score. Similarly, the analysis in the whole study group identified BMI (β = 0.168, p: 0.001), WHtR (β = 0.078, $p = 0.026$), systolic BP (β = 0.563, $p < 0.0001$), triglycerides (β = 0.422, $p < 0.0001$), HDL-C (β = -0.366, $p < 0.0001$), FPG (β = 0.287, $p < 0.0001$), and insulin levels (β = 0.672, $p < 0.0001$) as significantly associated with the MetSS z-score. Within the MetS group, BMI percentile (β = 0.388, $p = 0.022$), systolic BP (β = 0.589, $p < 0.0001$), FPG (β = 0.427, $p < 0.0001$), fasting insulin (β = 0.427, $p = 0.005$), and HDL-C levels (β = -0.407, $p < 0.0001$) were identified as influencing factors on the MetSS z-score.

Evaluation of ROC curves utilizing the PsiMS score and MetSS z-score

The discriminatory efficacy of the PsiMS score and MetSS z-score in distinguishing individuals with MetS from those without was illustrated through ROC curve analysis. The PsiMS score displayed an AUC of 0.75*3* (SE: 0.034, 9*5* % CI: 0.687-0.819, $p < 0.0001$) with a threshold of 4.5242, demonstrating sensitivity and specificity values of 68.*2* % and 68.*4* %, respectively, and a Youden index of 68.08. Similarly, the MetSS z-score exhibited an AUC of 0.88*5* (SE: 0.021, 9*5* % CI: 0.843-0.927, $p < 0.0001$) with a threshold of 1.1145, and sensitivity and

specificity values of 80.*7* % and 80.*4* %, respectively, resulting in a Youden index of 80.21. The comparison of AUC values between the PsiMS score and MetSS z-score was statistically significant (Difference -0.132, SE: 0.0400, Z-statistic -3.3031, $p = 0.0010$) (Fig. 2).

DISCUSSION

This study represents the initial investigation into the predictive abilities of the PsiMS score and the MetSS z-score as continuous measures to determine the risk of MetS in adolescents. Specifically, our findings identified the cut-off values of the PsiMS and MetSS z-scores for predicting the emergence of MetS in obese adolescents. Notably, an intriguing observation from our study was the positive correlation between the MetSS z-score and the PsiMS score with insulin sensitivity indices.

Previous studies have demonstrated a strong relationship between MetS and CVD risk (22,23). For instance, it has been shown that patients with MetS have significantly higher values of abdominal obesity, hypertriglyceridemia, hypertension, and insulin resistance (IR), all of which promote endothelial dysfunction and accelerate the development of vascular complications (24). The presence of MetS in teenagers is a critical risk factor for the emergence of CVD in adulthood. Since the pathogenesis of CVD begins during adolescence, it has been suggested that cardiometabolic risk factors should be evaluated during this period (25). In our study, we found that cardiometabolic risk factors were significantly elevated in adolescents with MetS, supporting previous research (26) and indicating that this group is potentially at risk for the development of CVD.

The MetSS z-score, a continuous scoring system, has been shown to predict CVD risk in young adults more reliably than traditional definitions of MetS (27-30). Recent research has introduced another simplified continuous score, the PsiMS score, which aligns with the current IDF definition of pediatric MetS (13). The PsiMS score offers advantages over the MetSS z-score, as it is easy to calculate and can

be utilized in clinical settings to compare values across different time periods and populations (13,14,31).

In our investigation, we observed a notably high prevalence of MetS in 44.*7* % of obese adolescents, as determined by the PsiMS score cut-off, and in 41.*4* % based on the MetSS *z*-score cut-off. These figures surpassed the prevalence rate diagnosed by the IDF, which was 35.*7* %. Our findings underscore the enhanced efficacy of utilizing the PsiMS score and MetSS *z*-score for evaluating MetS risk compared to the traditional dichotomous diagnostic approach, as reflected by the increased number of MetS diagnoses obtained through these continuous scoring systems. Consistent with prior studies, our results reaffirm that employing cMetS scoring systems facilitates the identification of a greater number of individuals at risk. This, in turn, enables the implementation of timely interventions, such as lifestyle modifications and dietary adjustments, as recommended in previous literature (32). Overall, our study suggests that a quantitative evaluation of MetS severity, rather than a binary classification, may offer a more accurate prediction of future CVD risk.

In a recent investigation, several factors were identified as significant independent predictors associated with higher PsiMS scores, including having two or more MetS criteria, BMI z-score, IR, and dyslipidemia. Our study revealed that levels of triglycerides and HDL-C were indicative independent predictors of the PsiMS score (33). Furthermore, within the MetS cohort, independent predictors influencing the MetSS z-score included BMI percentile, systolic BP, FPG, fasting insulin, and HDL-C levels.

The presence of MetS was associated with elevated cardiometabolic risk factors in obese adolescents, highlighting its role as an early CVD risk factor. Another study demonstrated that the PsiMS score was positively associated with the number of MetS components (33). Previous studies have investigated the relationship between the cMetS score and the number of MetS risk factors (34,35). These investigations revealed a direct correlation between the average

cMetS level and the number of MetS risk factors, with individuals manifesting three or more risk factors displaying elevated cMetS levels. The cMetS scores exhibited significant increases in children identified with MetS. In our study, both the PsiMS score and the MetSS z-score demonstrated prominent elevation in individuals diagnosed with MetS, serving as effective indicators of MetS risk. Notably, these scores exhibited a substantial increase in tandem with the number of MetS components, as reported in a recent study on Korean adolescents (36). Furthermore, our investigation illustrated a conspicuous rise in the cMetS z-score corresponding to the increase in the number of MetS components. These cMetS scores were identified as reliable tools for diagnosis and surveillance, exhibiting a positive association with cardiometabolic risk factors and underscoring their clinical utility in managing obese adolescents.

A recent investigation has highlighted a robust link between abdominal obesity and the MetS z-score among adolescents (37). Our own research observed that teenagers diagnosed with MetS exhibited notably higher WC compared to their non-MetS counterparts. Additionally, we discerned a positive correlation among the MetSS z-score, PsiMS score, and HC. Prior research emphasized the positive association of the MetS z-score with LDL-C and uric acid levels in adolescents (25). Another study illustrated that the PsiMS score was linked with MetS-related factors such as ALT, GGT, and uric acid during adulthood (26). In our study involving obese adolescents, the PsiMS score exhibited positive correlations with total cholesterol, LDL-C, GGT, and uric acid levels. However, the MetSS z-score displayed a positive association with serum uric acid levels. Notably, in the context of MetS, the PsiMS score showed positive correlations with total cholesterol. Likewise, the MetSS z-score demonstrated significant relationships with serum total cholesterol and uric acid levels. These insights underscore the importance of considering these parameters when assessing clinical CVD risk. The robust positive associations of the PsiMS score and the MetS z-score with various CVD

risk factors suggest their probable clinical significance in evaluating CVD risk, bolstering support from earlier studies (11,25,26).

A previous study has demonstrated that cMetS scores are associated with an elevated long-term risk of developing type *2* diabetes mellitus (33). Additionally, evidence indicates that a cMetS z-score remains closely associated with future diabetes risk in individuals presenting with MetS components (38,39). Another study has revealed strong positive associations between MetS severity scores and impaired glucose regulation, as well as a history of CVD (37). An adult study demonstrated a correlation between the PsiMS score and HOMA-IR in individuals with MetS (26). In our study, we found positive correlations between both the PsiMS score and the MetSS z-score, insulin, and HOMA-IR in obese adolescents. These findings suggest that higher MetS severity may contribute to the future risk of diabetes, potentially serving as an indicator of the underlying metabolic dysfunction driving abnormalities in individual MetS components.

A study revealed that the cMetS score based on z-scores exhibited the strongest predictive capability (AUC = 0.811) for identifying MetS in adolescents, with the highest specificity, consistent with findings from previous research (11). Another study on adolescents also demonstrated a high predictive power of cMetS based on z-scores (AUC > 0.885), aligning with our study results (40). We established threshold values for the PsiMS score (4.5242) and the MetSS z-score (1.1145), which showed moderate reliability for assessing MetS risk in obese adolescents.

Prior studies have demonstrated robust connections between various cMetS scores, particularly with PsiMS scores, showing a noteworthy AUC of 0.8*1* (9*5* % CI: 0.784-0.838) for z-scores and a specificity of 64.*4* % (11). Another investigation highlighted the similar performance of cMetS (AUC = 0.975) and PsiMS (AUC = 0.958) in identifying MetS risk in adolescents (14). Our study revealed a significant correlation between the PsiMS score and the MetS z-score, with the ROC analysis outcomes closely aligned with previous findings

(11). Notably, emphasizing the accuracy and efficiency of utilizing cMetS scores based on the PsiMS and MetSS z-scores for research purposes, our study underscored the superiority of the MetSS z-score over the PsiMS score in detecting MetS in obese adolescents, based on AUC values derived from ROC analysis.

The present study has several limitations that warrant consideration. Notably, the study cohort consisted of adolescents receiving medical attention at a hospital, which may limit the applicability of the findings to the broader adolescent population. Moreover, the cross-sectional nature of our study presents challenges in establishing causal relationships. Additional prospective research incorporating larger cohorts and long-term follow-up assessments is essential to elucidate the clinical relevance of the PsiMS and MetSS z-scores in obese adolescents.

CONCLUSION

Our study findings indicate that the rates of MetS diagnosis based on the PsiMS and MetSS z-scores—both of which are continuous metrics for assessing MetS—are notably higher in adolescents compared to the rates identified through traditional dichotomous diagnostic methods. Furthermore, we established a significant association between these scores and various metabolic parameters.

REFERENCES

1. Thivel D, Malina RM, Isacco L, Aucouturier J, Meyer M, Duché P. Metabolic syndrome in obese children and adolescents: dichotomous or continuous? Metab Syndr Relat Disord 2009;7(6):549-55. DOI: 10.1089/met.2008.0085
2. Wang HH, Lee DK, Liu M, Portincasa P, Wang DQ. Novel Insights into the Pathogenesis and Management of the Metabolic Syndrome. Pediatr Gastroenterol Hepatol Nutr 2020;23(3):189-230. DOI: 10.5223/pghn.2020.23.3.189

3. Christian Flemming GM, Bussler S, Körner A, Kiess W. Definition and early diagnosis of metabolic syndrome in children. J Pediatr Endocrinol Metab 2020;33(7):821-33. DOI: 10.1515/jpem-2019-0552
4. Srinivasan SR, Myers L, Berenson GS. Predictability of childhood adiposity and insulin for developing insulin resistance syndrome (syndrome X) in young adulthood: the Bogalusa heart study. Diabetes 2002;51(1):204-9. DOI: 10.2337/diabetes.51.1.204
5. Sharma R. Continuous Metabolic Syndrome Score in Children: How Useful is it? Indian J Pediatr 2019;86(10):881-2. DOI: 10.1007/s12098-019-03047-7
6. Weihe P, Weihrauch-Blüher S. Metabolic Syndrome in Children and Adolescents: Diagnostic Criteria, Therapeutic Options and Perspectives. Curr Obes Rep 2019;8(4):472-9. DOI: 10.1007/s13679-019-00357-x
7. Ahrens W, Moreno LA, Mårild S, Molnár D, Siani A, De Henauw S, et al; IDEFICS consortium. Metabolic syndrome in young children: definitions and results of the IDEFICS study. Int J Obes (Lond) 2014;38:S4-14. DOI: 10.1038/ijo.2014.130
8. Gustafson JK, Yanoff LB, Easter BD, Brady SM, Keil MF, Roberts MD, et al. The stability of metabolic syndrome in children and adolescents. J Clin Endocrinol Metab 2009;94(12):4828-34. DOI: 10.1210/jc.2008-2665
9. Kahn R, Buse J, Ferrannini E, Stern M; American Diabetes Association; European Association for the Study of Diabetes. The metabolic syndrome: time for a critical appraisal: joint statement from the American Diabetes Association and the European Association for the Study of Diabetes. Diabetes Care 2005;28(9):2289-304. DOI: 10.2337/diacare.28.9.2289
10. Heshmat R, Heidari M, Ejtahed HS, Motlagh ME, Mahdavi-Gorab A, Ziaodini H, et al. Validity of a continuous metabolic syndrome score as an index for modeling metabolic syndrome

in children and adolescents: the CASPIAN-V study. Diabetol Metab Syndr 2017;9:89. DOI: 10.1186/s13098-017-0291-4

11. Fernández-Aparicio Á, Perona JS, Schmidt-RioValle J, Montero-Alonso MA, Navarro-Pérez CF, González-Jiménez E. cMetS Based on Z-Scores as an Accurate and Efficient Scoring System to Determine Metabolic Syndrome in Spanish Adolescents. J Pers Med 2022;13(1):10. DOI: 10.3390/jpm13010010
12. Soldatovic I, Vukovic R, Culafic D, Gajic M, Dimitrijevic-Sreckovic V. siMS score: simple method for quantifying metabolic syndrome. PLoS One 2016;11(1):e0146143. DOI: 10.1371/journal.pone.0146143
13. Vukovic R, Milenkovic T, Stojan G, Vukovic A, Mitrovic K, Todorovic S, et al. Pediatric siMS score: a new, simple and accurate continuous metabolic syndrome score for everyday use in pediatrics. PLoS One 2017;12(12):e0189232. DOI: 10.1371/journal.pone.0189232
14. Lee YJ, Seo MY, Kim SH, Park MJ. Validity of the pediatric simple metabolic syndrome score. Obes Res Clin Pract 2020;14(6):508-13. DOI: 10.1016/j.orcp.2020.09.009
15. Zimmet P, Alberti KG, Kaufman F, Tajima N, Silink M, Arslanian S, et al; IDF Consensus Group. The metabolic syndrome in children and adolescents— An IDF consensus report. Pediatr Diabetes 2007;8(5):299-306. DOI: 10.1111/j.1399-5448.2007.00271.x
16. Ozturk A, Mazicioglu MM, Hatipoglu N, Budak N, Keskin G, Yazlak Z, et al. Reference body mass index curves for Turkish children *6* to 1*8* years of age. J Pediatr Endocrinol Metab 2008;21(9):827e836. DOI: 10.1515/jpem.2008.21.9.827
17. Demir K, Özen S, Konakçı E, Aydın M, Darendeliler F. A Comprehensive Online Calculator for Pediatric Endocrinologists: ÇEDD Çözüm/TPEDS Metrics. J Clin Res Pediatr Endocrinol 2017;9(2):182-4. DOI: 10.4274/jcrpe.4526

18. Li C, Ford ES, Mokdad AH, Cook S. Recent trends in waist circumference and waist-height ratio among US children and adolescents. Pediatrics 2006;118(5):1390-8. DOI: 10.1542/peds.2006-1062
19. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta cell function from fasting plasma glucose and insulin concentrations in men. Diabetologia 1985;28(7): 412-29. DOI: 10.1007/BF00280883
20. Keskin M, Kurtoglu S, Kendirci M, Atabek ME, Yazici C. Homeostasis model assessment is more reliable than the fasting glucose/ insulin ratio and quantitative insulin sensitivity check index for assessing insulin resistance among obese children and adolescents. Pediatrics 2005;115(4):e500-3. DOI: 10.1542/peds.2004-1921
21. Gurka MJ, Ice CL, Sun SS, Deboer MD. A confirmatory factor analysis of the metabolic syndrome in adolescents: an examination of sex and racial/ethnic differences. Cardiovasc Diabetol 2012;11:128. DOI: 10.1186/1475-2840-11-128
22. Guembe MJ, Fernandez-Lazaro CI, Sayon-Orea C, Toledo E, Moreno-Iribas C; RIVANA Study Investigators. Risk for cardiovascular disease associated with metabolic syndrome and its components: a 13-year prospective study in the RIVANA cohort. Cardiovasc Diabetol 2020;19(1):195. DOI:10.1186/s12933-020-01166-6
23. Lin JJ, Dai PY, Zhang J, Guan YQ, Gong WW, Yu M, et al. Association between metabolic syndrome severity score and cardiovascular disease: results from a longitudinal cohort study on Chinese adults. Front Endocrinol (Lausanne) 2024;15:1341546. DOI: 10.3389/fendo.2024.1341546
24. Sreckovic B, Dimitrijevic-Sreckovic V, Soldatovic I, Colak E, Sumarac-Dumanovic M, Janeski H, et al. Homocysteine is a marker for metabolic syndrome and atherosclerosis. Diabetes

Metab. Syndr 2017;11(3):179-82. DOI: 10.1016/j.dsx.2016.08.026

25. Lee AM, Gurka MJ, DeBoer MD. Correlation of metabolic syndrome severity with cardiovascular health markers in adolescents. Metabolism 2017;69:87-95. DOI: 10.1016/j.metabol.2017.01.008

26. Dimitrijevic-Sreckovic V, Petrovic H, Dobrosavljevic D, Colak E, Ivanovic N, Gostiljac D, et al. siMS score- method for quantification of metabolic syndrome, confirms co-founding factors of metabolic syndrome. Front Genet 2023;13:1041383. DOI: 10.3389/fgene.2022.1041383

27. Merry TL, Metcalf P, Scragg R, Gearry R, Foster M, Krebs JD, et al. Metabolic syndrome severity score (MetSSS) associates with metabolic health status in multi-ethnic Aotearoa New Zealand cohorts. Diabetes Res Clin Pract 2022;192:110088. DOI: 10.1016/j.diabres.2022.110088

28. Honarvar M, Mehran L, Masoumi S, Agahi S, Khalili S, Azizi F, et al. Independent association between age- and sex-specific metabolic syndrome severity score and cardiovascular disease and mortality. Sci Rep 2023;13(1):14621. DOI: 10.1038/s41598-023-41546-y

29. Magnussen CG, Cheriyan S, Sabin MA, Juonala M, Koskinen J, Thomson R, et al. Continuous and dichotomous metabolic syndrome definitions in youth predict adult type *2* diabetes and carotid artery intima media thickness: the cardiovascular risk in Young Finns study. J Pediatr 2016;171:97-103.e1-3. DOI: 10.1016/j.jpeds.2015.10.093

30. Kelly AS, Steinberger J, Jacobs DR, Hong CP, Moran A, Sinaiko AR. Predicting cardiovascular risk in young adulthood from the metabolic syndrome, its component risk factors, and a cluster score in childhood. Int J Pediatr Obes 2011;6(2-2):e283-9. DOI: 10.3109/17477166.2010.528765

31. Khoshhali M, Heshmat R, Esmaeil Motlagh M, Ziaodini H, Hadian M, Aminaei T, et al. Comparing the validity of continuous metabolic syndrome risk scores for predicting pediatric metabolic syndrome: the CASPIAN-V study. J Pediatr Endocrinol Metab 2019;32(4):383-9. DOI: 10.1515/jpem-2018-0384
32. DeBoer MD, Gurka MJ. Clinical utility of metabolic syndrome severity scores: considerations for practitioners. Diabetes Metab Syndr Obes 2017;10:65-72. DOI: 10.2147/DMSO.S101624
33. Ferreira S, Mendes J, Couto D, Ferreira D, Rêgo C. Nonalcoholic Fatty Liver Disease and Continuous Metabolic Syndrome in Adolescents with Overweight/Obesity. Acta Med Port 2024;37(3):177-86. DOI: 10.20344/amp.19834
34. Eisenmann JC, Laurson KR, DuBose KD, Smith BK, Donnelly JE. Construct validity of a continuous metabolic syndrome score in children. Diabetol Metab Syndr 2010;2:8. DOI: 10.1186/1758-5996-2-8
35. Sawant SP, Amin AS. Use of Continuous Metabolic Syndrome Score in Overweight and Obese Children. Indian J Pediatr 2019;86(10):909-14. DOI: 10.1007/s12098-019-02994-5
36. Song M, Kang S, Kang H. The Association Between Obesity Measures and Metabolic Syndrome Risk in Korean Adolescents Aged 10-1*8* Years. J Multidiscip Healthc 2024;17:1769-76. DOI: 10.2147/JMDH.S461406
37. Summer SS, Jenkins T, Inge T, Deka R, Khoury JC. Association of diet quality, physical activity, and abdominal obesity with metabolic syndrome z-score in black and white adolescents in the US. Nutr Metab Cardiovasc Dis 2022;32(2):346-54. DOI: 10.1016/j.numecd.2021.10.021
38. DeBoer MD, Gurka MJ, Woo JG, Morrison JA. Severity of the metabolic syndrome as a predictor of type *2* diabetes between childhood and adulthood: the Princeton Lipid Research Cohort

Study. Diabetologia 2015;58(12):2745-52. DOI: 10.1007/s00125-015-3759-5

39. Pandit D, Chiplonkar S, Khadilkar A, Kinare A, Khadilkar V. Efficacy of a continuous metabolic syndrome score in Indian children for detecting subclinical atherosclerotic risk. Int J Obes [Internet] 2011;35:1318-24. DOI:10.1038/ijo.2011.138

40. Okosun IS, Lyn R, Davis-Smith M, Eriksen M, Seale P. Validity of a continuous metabolic risk score as an index for modeling metabolic syndrome in adolescents. Ann Epidemiol 2010;20(11):843-51. DOI: 10.1016/j.annepidem.2010.08.001

Table I. Demographic and clinical features of obese adolescents with and without metabolic syndrome

Variable		**Groups**		
	All participants	**Non-metabolic syndrome**	**Metabolic syndrome**	***p*-value**
Sex (female/male) (*n*, %)	24*6* (100)	85/7*3* (53.8/46.2)	43/4*5* (48.9/51.1)	0.458
Age (years)	13.7*7* (3.67)	13.6*5* (3.47)	13.*9* (3.42)	0.091
Weight (kg)	77.*9* (24.3)	73.*5* (20.4)	85.*7* (31)	< 0.0001
Height (cm)	15*8* (14.9)	15*7* (12.1)	161.*2* (15.8)	0.008
Height-SDS	0.146*1* ± 1.1323	0.138*2* ± 1.1238	0.160*5* ± 1.538	0.883
BMI (kg/m^2)	30.0*9* (5.68)	29.3*9* (4.33)	31.5*6* (7.34)	< 0.0001
Percentile of BMI (%)	98.1*8* (1.62)	97.8*7* (1.64)	98.4*0* (1.28)	< 0.0001
BMI Z-score	2.0*9* (0.353)	2.02*7* (0.328)	2.14*4* (0.434)	< 0.0001
WC (cm)	98.*5* (15)	9*5* (12)	10*2* (15)	< 0.0001
HC (cm)	107.*5* (15)	10*5* (13)	111.*5* (15)	< 0.0001
WHCR	0.924*4* (0.099)	0.923*0* (0.103)	0.927*9* (0.096)	< 0.0001
WHtR	0.615*9* (0.070)	0.604*7* (0.060)	0.632*3* (0.083)	0.104
SBP (mmHg)	12*0* (20)	11*0* (20)	13*0* (13.8)	< 0.0001
DBP (mmHg)	8*0* (10)	7*0* (10)	8*5* (10)	< 0.0001
MBP (mmHg)	9*0* (13.3)	83.*3* (13.3)	98.*3* (11.25)	< 0.0001
Fasting glucose (mg/dl)	9*1* (10.2)	9*0* (9.9)	9*2* (13)	< 0.0001
Fasting insulin (U/ml)	19.9*0* (12.34)	18.0*5* (12.45)	22.9*0* (11.70)	< 0.0001
HOMA-IR	4.286*4* (2.96)	4.018*8* (2.90)	5.291*7* (3.28)	<

				0.0001
IR (*n*, %)	18*5* (75.2)	10*8* (68.4)	7*7* (87.5)	0.001
Total cholesterol (mg/dl)	16*1* (45.5)	15*9* (44.5)	16*7* (44)	0.472
Triglycerides (mg/dl)	11*2* (79)	9*9* (63)	15*0* (104.4)	< 0.0001
LDL-C (mg/dl)	90.2*5* (34.2)	90.1*5* (35.7)	90.6*0* (31.3)	0.884
HDL-C (mg/dl)	4*5* (12)	4*7* (11)	3*9* (13)	< 0.0001
ALT (U/l)	1*9* (11.3)	1*8* (10.9)	2*1* (14)	0.159
AST (U/l)	2*0* (7.7)	19.*5* (8.1)	2*0* (7.3)	0.779
GGT (U/l)	16.*5* (11.8)	16.*5* (12)	1*7* (10.5)	0.382
Serum ferritin (µg/l)	32.7*0* (33.25)	31.5*0* (32.1)	37.1*0* (38.65)	0.245
Serum uric acid (mg/dl)	5.4*0* (1.6)	5.3*0* (1.5)	5.7*0* (1.9)	0.362
HbA1c (%)	5.3*0* (0.5)	5.3*0* (0.5)	5.4*0* (0.4)	0.260
FT*4* (ng/dl)	1.1*5* (0.23)	1.1*4* (0.22)	1.2*0* (0.25)	0.098
TSH (mIU/ml)	2.3*8* (1.69)	2.3*3* (1.76)	2.4*6* (1.53)	0.580
PsiMS score	4.278*5* (2.974 9)	3.599*3* (2.1535)	5.841*9* (3.7880)	< 0.0001
MetSS Z-score	1.011*5* ± 0.550705	0.7562*3* ± 0.43253	1.4698*2* ± 0.43084	< 0.0001
MetS percentile (%)	84.2*8* (17.20)	79.5*6* (18.55)	92.0*4* (8.26)	< 0.0001

Values are expressed as mean ± standard deviation or median (IQR). BMI: body mass index; WC: waist circumference; HC: hip circumference; WHCR: waist circumference/hip circumference ratio; WHtR: waist circumference/height ratio; SBP: systolic blood pressure; DBP: diastolic blood pressure; MBP: mean blood pressure; HOMA-IR: homeostasis model assessment for insulin resistance; IR: insulin resistance; LDL-C: low-density lipoprotein-cholesterol; HDL-C: high-density lipoprotein-cholesterol; ALT: alanine aminotransferase; AST: aspartate aminotransferase; GGT: gamma-glutamyl transferase; FT4: free T4; TSH: thyroid-stimulating hormone; PsiMS score: pediatric simple metabolic syndrome score; MetSS z-score: metabolic

syndrome severity z-score; MetS percentile: metabolic syndrome percentile.

Table II. Pediatric siMS score and MetSS Z-score in groups according to the number of MetS components

Variable		**Number of MetS components**				***p*-value**
		1 (*n*: 81)	*2* (*n*: 99)	*3* (*n*: 57)	*4* (*n*: 9)	
PsiMS score	Mean	3.116	5.041	5.757	7.096	< 0.0001
	SD	1.233	2.331	2.540	2.206	
MetS Z-score	Mean	0.527	1.057	1.452	2.073	< 0.0001
	SD	0.393	0.348	0.3919	0.358	

Table III. Bivariate correlations between the pediatric siMS score and metabolic variables in obese adolescents

Variable	**All obese adolescents**		**Non-metabolic syndrome**		**Metabolic syndrome**	
	r	*p*	*r*	*p*	*r*	*p*
Age	-0.08	0.214	-0.159	0.046	-0.11	0.31
BMI (kg/m^2)	0.045	0.485	-0.001	0.991	-0.17	0.113
Percentile of BMI (%)	0.141	0.027	0.156	0.051	-0.108	0.317
BMI Z-score	0.126	0.048	0.127	0.112	-0.104	0.335
HC (cm)	0.05	0.433	-0.003	0.967	-0.123	0.255
Total cholesterol (mg/dl)	0.164	0.01	0.22	0.005	0.398	< 0.0001
LDL-C (mg/dl)	0.145	0.023	0.247	0.002	0.053	0.627
ALT (U/l)	0.07	0.276	0.059	0.46	-0.007	0.951
AST (U/l)	0.034	0.603	0.033	0.676	-0.011	0.92
GGT (U/l)	0.241	0.012	0.251	0.036	0.169	0.312
Serum uric acid	0.149	0.024	0.079	0.336	0.191	0.09
HbA1c	0.023	0.723	0.066	0.429	-0.045	0.684
Fasting insulin (U/ml)	0.22	0.001	0.228	0.004	0.089	0.413
HOMA-IR	0.192	0.00	0.222	0.005	0.04	0.712

		3				
TSH	0.048	0.46	0.111	0.169	0.079	0.464
Ferritin	0.047	0.487	0.026	0.761	-0.011	0.926

Table IV. Bivariate correlations between the METSS Z-score and metabolic variables in obese adolescents

Variable	**All obese adolescents**		**Non-metabolic syndrome**		**Metabolic syndrome**	
	r	***p***	***r***	***p***	***r***	***p***
Age	0.092	0.148	-0.027	0.738	0.17	0.113
HC (cm)	0.367	< 0.0001	0.299	< 0.0001	0.284	0.007
Total cholesterol (mg/dl)	0.046	0.476	0.074	0.358	0.25	0.02
LDL-C (mg/dl)	0.105	0.099	0.091	0.254	0.188	0.079
ALT (U/l)	0.168	0.008	0.072	0.369	0.165	0.128
AST (U/l)	0.049	0.444	-0.057	0.477	0.097	0.377
GGT (U/l)	0.31	0.001	0.347	0.003	0.235	0.156
Serum uric acid	0.221	0.001	0.108	0.19	0.418	< 0.0001
HbA1c	0.006	0.922	0.033	0.697	-0.096	0.38
Fasting insulin (U/ml)	0.305	< 0.0001	0.414	< 0.0001	0.021	0.846
HOMA-IR	0.305	< 0.0001	0.422	< 0.0001	0.036	0.739
TSH	-0.005	0.933	0.098	0.225	-0.108	0.317
Ferritin	0.136	0.044	0.024	0.774	0.156	0.173
PsiMS score	0.659	< 0.0001	0.606	< 0.0001	0.503	< 0.0001

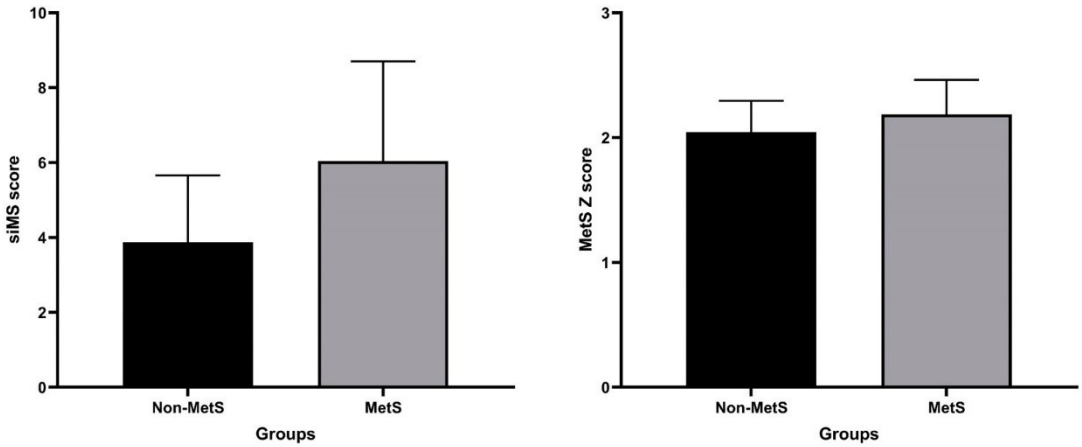

Figure 1. Comparison of pediatric siMS and metabolic syndrome severity Z-scores between obese adolescents with and without metabolic syndrome.

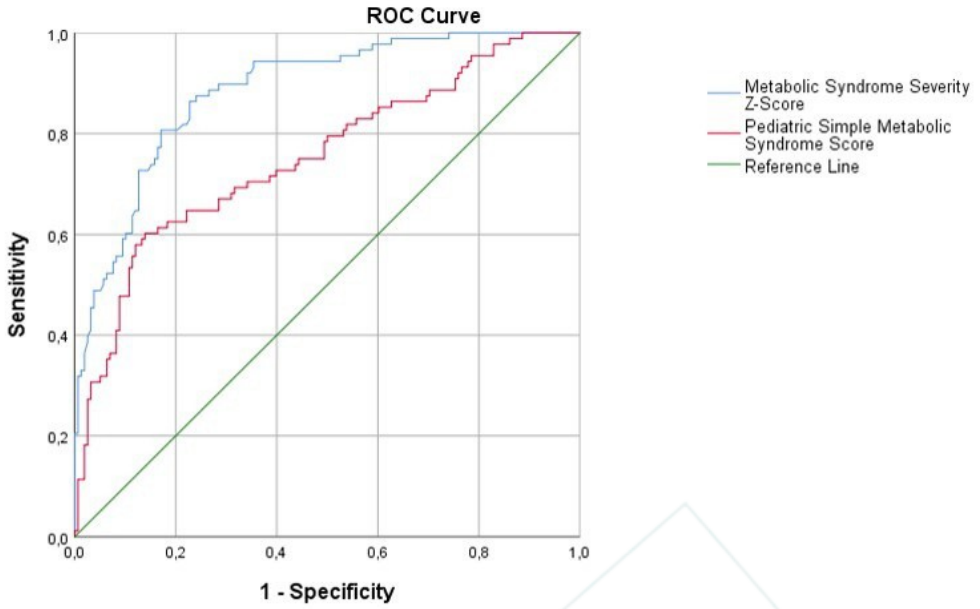

Figure 2. Receiver operating characteristic curve analysis demonstrating the predictive performance of the pediatric siMS score and metabolic syndrome severity Z-score for the detection of metabolic syndrome in obese adolescents.